
EXHIBIT 20

Water Management Goal

Cost Appendix

Produced Water in the San Joaquin Valley

Technical Report

**SAN JOAQUIN RIVER
RESTORATION PROGRAM**

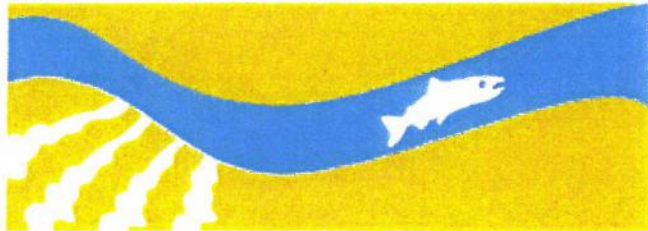


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List of Abbreviations and Acronyms

bbl	barrel
BWRO	brackish water reverse osmosis
CRWQCB	California Regional Water Quality Control Board
DAF	dissolved air flotation
ENR	Engineering News-Record
kWh	kilowatt-hour
kWh/bbl	kilowatt-hour per barrel
kWh/m ³	kilowatt-hour per cubic meter
mg/L	milligrams per liter
Produced Water	water produced as a byproduct of oil and gas extraction operations
SWRO	seawater reverse osmosis
TDS	total dissolved solids
UIC	underground injection control

Treatment Costs

This appendix contains a summary of the source material used for calculating treatment costs of produced water in the Central Valley, documented in Chapter 4 of the main document. The costs provided herein are for the capital costs and operations and maintenance per barrel of water for the treatment of the produced water annualized over the life cycle of the treatment plant. Costs for energy and disposal of brine are also provided as costs per barrel. The costs provided do not include contingencies, non-contract costs, allowances for unlisted items, or the capital costs for moving water from where it is produced or to the final delivery point. These costs were developed through experience on past projects and are based on normal market conditions. No warranty, promise, guarantee, or representation, either expressed or implied, is given that proposals, bids, project construction costs, or costs of operations and maintenance functions will not vary significantly from the costs provided.

Treatment Objectives

Table 1 contains a summary of key water quality parameters of produced water, along with effluent limits for irrigation reuse of produced water.

Table 1. Produced Water Parameters and Beneficial Reuse Water Quality Goals

Water Quality Parameter	Units	Produced Water Value	Beneficial Reuse Goal
Total Dissolved Solids	mg/L	200-62,000 ¹	500-2,000 ³
Oil and Grease	mg/L	2-565 ² 50-400 ³	35 ³
Boron	mg/L	5-95 ²	1.3 ⁴

¹ Source: DOGGR 1998

² Source: Ahmadun et al. 2009

³ Source: Muraleedaraan et al. 2009

⁴ Source: California Regional Water Quality Control Board (CRWQCB) 2012

Key:

mg/L = milligrams per liter

Treatment Processes

The proposed treatment processes for reclamation of oil field produced water are dissolved air flotation (DAF) for removal of oil and grease, followed by reverse osmosis membrane filtration for removal of total dissolved solids (TDS). Two types of reverse osmosis membranes are available, depending on the TDS concentration. For produced water having less than 25,000 ppm TDS, a brackish water reverse osmosis (BWRO) membrane is used. When the TDS is higher than 25,000 mg/L, a seawater reverse

osmosis (SWRO) membrane is used. Table 2 contains the operating parameters for DAF, BWRO, and SWRO treatment processes. Treatment costs and removal efficiencies presented in this appendix were developed assuming produced water passes through oil and grease treatment and reverse osmosis treatment one time.

Table 2. Operating Parameters for Produced Water Treatment Processes

Water Quality Parameter	Produced Water Most Probable Value	Best Available Treatment Technology	Removal Efficiency	Treated Water Effluent Concentration
Oil and Grease	>70 mg/L	DAF ¹	93% ¹	19 mg/L ² -25 mg/L ³
Total Dissolved Solids	<25,000 mg/L	BWRO ¹	50-85% ¹	100-1,500 mg/L ¹
	>25,000 mg/L	SWRO ¹	30-60% ¹	100-400 mg/L ¹

¹ Source: Colorado School of Mines 2009

² Source: Ahmadun et al. 2009

³ Source: Argonne National Laboratory 2004

Key:

BWRO = brackish water reverse osmosis

DAF = dissolved air flotation

mg/L = milligrams per liter

SWRO = seawater reverse osmosis

Treatment Cost Components

Published values for capital costs and operation and maintenance costs are provided in Table 3. The capital costs are based on a 3.5 percent discount rate and the life cycles stated in Table 3. Capital costs and operation and maintenance costs were developed for a 50,000 barrel per day treatment capacity.

Table 3. Capital and Operations/Maintenance Costs for Produced Water Treatment Processes

Water Treatment Process	Capital Life Cycle (year)	Capital Cost ^{3,4}	Operations/Maintenance Cost ³
DAF	40	\$0.051/bbl ¹	\$0.07/bbl ²
BWRO	7 ¹	\$0.018-\$0.089/bbl ¹	\$0.03/bbl ¹
SWRO	7 ¹	\$0.064-\$0.150/bbl ¹	\$0.09/bbl ¹

Notes:

¹ Source: Colorado School of Mines 2009

² Source: Argonne National Laboratory 2004

³ Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.

⁴ Capital costs are annualized over the life cycle of the water treatment process at a discount rate of 3.5%

Key:

bbl = barrel

BWRO = brackish water reverse osmosis

DAF = dissolved air flotation

mg/L = milligrams per liter

SWRO = seawater reverse osmosis

Energy consumption rates for reverse osmosis treatment are known to be directly related to the concentration of salinity in the feed water (Nexus 2010). As of 2010, the energy consumption rate for reverse osmosis filtration of seawater was approximately 2 kilowatt-hours per cubic meter (kWh/m³) (CetAqua 2010). Given that seawater has 36,000 mg/L salinity, the energy consumption rates for various TDS values can be calculated using proportionality.

Energy consumption rates for reverse osmosis treatment of produced water are provided in Table 4.

Table 4. Energy Consumption Rates for Reverse Osmosis Treatment

Influent TDS Concentration (mg/L)	Energy Consumption Rate ^{1,2} (kWh/bbl)
500	0.004
1,000	0.009
10,000	0.089
30,000	0.267
60,000	0.533

¹ Source: Nexus 2010

² Source: CetAqua 2010

Key:

kWh/bbl = kilowatt hours per barrel

mg/L = milligrams per liter

TDS = total dissolved solids

The current electrical power rates charged by Pacific Gas & Electric for Kern County, CA customers are used in the spreadsheet to calculate energy costs associated with RO membrane filtration. In the spreadsheet, the tier 3 rate of \$0.29/kWh is used. The tabulated values for each tier are provided on Table 5. Actual electricity rates will vary depending on seasonal and peak and off-peak use.

Table 5. Electrical Power Costs for Kern County, California

Tier	Cost ^{1,2} (\$/kWh)
1	0.12
2	0.13
3	0.29
4	0.40
5	0.40

Notes:

¹ Source: Pacific Gas & Electric 2014

² Costs provided represent only the cost of power and do not include capital costs for transmission of power to treatment facility.

Key:

kWh = kilowatt hour

Table 6 contains the typical costs associated with disposal of oil field brine. Brine disposal is assumed to occur via injection into an Underground Injection Control (UIC) Class II injection well (Argonne National Laboratory 2004).

Table 6. Oil Field Brine Disposal Costs

Item	Cost (\$/bbl) ³
Brine Haulage Fee	0.66-1.14 ¹
Injection Well Disposal	0.01-0.10 ²

Notes:

¹ Source: McCurdy 2005

² Source: Argonne National Laboratory 2004

³ Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.

Key:

bbl = barrel

Treatment Costs Summary

This section uses the information provided in the previous sections of this appendix to develop a range of treatment costs bases on the range of required desalination, capital costs, recovery ratios, and brine disposal costs. Costs are given in \$/bbl and \$/acre-foot of water that is available for agriculture at 500 to 3,000 mg/L TDS. This water is referred to as reclaimed water. Costs presented in Tables 7 through 10 provide minimum estimated treatment and brine haul and disposal costs, Tables 11 through 14 provide midpoint estimated treatment and brine haul and disposal costs, and Tables 15 through 19 provide maximum estimated treatment and brine haul and disposal costs. Midpoint treatment costs presented in Table 11 through 14 are used in the main body of the Produced Water in the San Joaquin Valley Technical Report.

Table 7. Minimum Range of Oil and Grease and Reverse Osmosis Treatment Costs for Produced Water^{1,2,3,4}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	\$0.12	n/a	n/a	n/a	n/a	500	\$940	n/a	n/a	n/a	n/a
1,000	\$0.17	\$0.15	\$0.12	n/a	n/a	1,000	\$1,300	\$1,150	\$940	n/a	n/a
10,000	\$0.24	\$0.24	\$0.24	\$0.22	\$0.21	10,000	\$1,900	\$1,850	\$1,850	\$1,750	\$1,650
30,000	\$0.50	\$0.50	\$0.49	\$0.48	\$0.47	30,000	\$3,900	\$3,800	\$3,800	\$3,700	\$3,600
60,000	\$0.92	\$0.92	\$0.91	\$0.90	\$0.89	60,000	\$7,100	\$7,100	\$7,100	\$7,000	\$6,900

Notes:¹ Sources used to develop costs are documented in Tables 1 through 5.² Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.³ Capital costs are annualized over the life cycle of the water treatment process at a discount rate of 3.5%.⁴ Costs provided include the cost of power but do not include capital costs for transmission of power to treatment facility. Costs do not include capital or operation and maintenance costs for pumping produced water to water treatment facility and pumping reclaimed water to site of end use.**Key:**

bbl = barrel

ENR = Engineering News-Record

mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 8. Minimum Brine Haul Costs^{1,2}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	n/a	n/a	n/a	n/a	n/a	500	n/a	n/a	n/a	n/a	n/a
1,000	\$0.07	\$0.04	n/a	n/a	n/a	1,000	\$560	\$280	n/a	n/a	n/a
10,000	\$0.28	\$0.27	\$0.27	\$0.24	\$0.21	10,000	\$2,200	\$2,100	\$2,100	\$1,850	\$1,600
30,000	\$0.54	\$0.53	\$0.53	\$0.51	\$0.49	30,000	\$4,200	\$4,100	\$4,100	\$3,900	\$3,800
60,000	\$1.54	\$1.53	\$1.53	\$1.50	\$1.48	60,000	\$12,000	\$12,000	\$12,000	\$11,500	\$11,500

Notes:¹ Sources used to develop costs are documented in Table 6.² Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.**Key:**

bbl = barrel

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mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 9. Minimum Brine Injection Costs^{1,2}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	n/a	n/a	n/a	n/a	n/a	500	n/a	n/a	n/a	n/a	n/a
1,000	\$0.001	\$0.001	n/a	n/a	n/a	1,000	\$9	\$4	n/a	n/a	n/a
10,000	\$0.004	\$0.004	\$0.004	\$0.004	\$0.003	10,000	\$33	\$32	\$31	\$28	\$24
30,000	\$0.01	\$0.01	\$0.01	\$0.01	\$0.01	30,000	\$63	\$62	\$62	\$60	\$58
60,000	\$0.02	\$0.02	\$0.02	\$0.02	\$0.02	60,000	\$180	\$180	\$180	\$175	\$175

Notes:

¹ Sources used to develop costs are documented in Table 6.

² Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.

Key:

bbl = barrel

ENR = Engineering News-Record

mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 10. Sum of Minimum Oil and Grease and Reverse Osmosis Treatment, Brine Haul, and Brine Injection Costs^{1,2,3,4,5}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	\$0.12	n/a	n/a	n/a	n/a	500	\$940	n/a	n/a	n/a	n/a
1,000	\$0.24	\$0.18	\$0.12	n/a	n/a	1,000	\$1,900	\$1,400	\$940	n/a	n/a
10,000	\$0.53	\$0.52	\$0.50	\$0.46	\$0.42	10,000	\$4,100	\$4,000	\$3,900	\$3,600	\$3,300
30,000	\$1.04	\$1.03	\$1.03	\$1.00	\$0.96	30,000	\$8,100	\$8,000	\$8,000	\$7,700	\$7,500
60,000	\$2.48	\$2.47	\$2.46	\$2.42	\$2.38	60,000	\$19,500	\$19,000	\$19,000	\$19,000	\$18,500

Note:

¹ Values from Tables 7, 8, and 9 may not add to totals presented in Table 10 due to rounding.² Sources used to develop costs are documented in Tables 1 through 6.³ Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.⁴ Capital costs are annualized over the life cycle of the water treatment process at a discount rate of 3.5%.⁵ Costs provided include the cost of power but do not include capital costs for transmission of power to treatment facility. Costs do not include capital or operation and maintenance costs for pumping produced water to water treatment facility and pumping reclaimed water to site of end use.

Key:

bbl = barrel

ENR = Engineering News-Record

mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 11. Mean Range of Oil and Grease and Reverse Osmosis Treatment Costs for Produced Water^{1,2,3,4}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	\$0.12	n/a	n/a	n/a	n/a	500	\$940	n/a	n/a	n/a	n/a
1,000	\$0.20	\$0.16	\$0.12			1,000	\$1,500	\$1,250	\$940		
10,000	\$0.29	\$0.29	\$0.28	\$0.27	\$0.25	10,000	\$2,300	\$2,200	\$2,200	\$2,100	\$1,900
30,000	\$0.58	\$0.57	\$0.57	\$0.55	\$0.54	30,000	\$4,500	\$4,400	\$4,400	\$4,300	\$4,200
60,000	\$1.06	\$1.06	\$1.06	\$1.04	\$1.02	60,000	\$8,300	\$8,200	\$8,200	\$8,100	\$7,900

Notes:

¹ Sources used to develop costs are documented in Tables 1 through 5.

² Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.

³ Capital costs are annualized over the life cycle of the water treatment process at a discount rate of 3.5%.

⁴ Costs provided include the cost of power but do not include capital costs for transmission of power to treatment facility. Costs do not include capital or operation and maintenance costs for pumping produced water to water treatment facility and pumping reclaimed water to site of end use.

Key:

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mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 12. Mean Brine Haul Costs^{1,2}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	n/a	n/a	n/a	n/a	n/a	500	n/a	n/a	n/a	n/a	n/a
1,000	\$0.10	\$0.05	n/a	n/a		1,000	\$770	\$390	n/a	n/a	n/a
10,000	\$0.38	\$0.37	\$0.36	\$0.32	\$0.28	10,000	\$3,000	\$2,900	\$2,800	\$2,500	\$2,200
30,000	\$0.73	\$0.72	\$0.72	\$0.69	\$0.67	30,000	\$5,700	\$5,600	\$5,600	\$5,400	\$5,200
60,000	\$2.10	\$2.09	\$2.08	\$2.05	\$2.01	60,000	\$16,500	\$16,000	\$16,000	\$16,000	\$15,500

Notes:

¹ Sources used to develop costs are documented in Table 6.² Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.

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bbl = barrel

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mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 13. Mean Brine Injection Costs^{1,2}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	n/a	n/a	n/a	n/a	n/a	500	n/a	n/a	n/a	n/a	n/a
1,000	\$0.01	\$0.003	n/a	n/a	n/a	1,000	\$ 47	\$24	n/a		
10,000	\$0.02	\$0.02	\$0.02	\$0.02	\$0.02	10,000	\$180	\$175	\$170	\$150	\$135
30,000	\$0.04	\$0.04	\$0.04	\$0.04	\$0.04	30,000	\$350	\$340	\$340	\$330	\$320
60,000	\$0.13	\$0.13	\$0.13	\$0.13	\$0.12	60,000	\$1,000	\$990	\$990	\$970	\$950

Notes:

¹ Sources used to develop costs are documented in Table 6.

² Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.

Key:

bbl = barrel

ENR = Engineering News-Record

mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 14. Sum of Mean Oil and Grease and Reverse Osmosis Treatment, Brine Haul, and Brine Injection Costs^{1,2,3,4,5}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	\$0.12	n/a	n/a	n/a	n/a	500	\$940	n/a	n/a	n/a	n/a
1,000	\$0.30	\$0.21	\$0.12	n/a	n/a	1,000	\$2,300	\$1,650	\$940	n/a	n/a
10,000	\$0.70	\$0.68	\$0.67	\$0.61	\$0.55	10,000	\$5,400	\$5,300	\$5,200	\$4,700	\$4,200
30,000	\$1.35	\$1.34	\$1.33	\$1.29	\$1.25	30,000	\$10,500	\$10,500	\$10,500	\$10,000	\$9,700
60,000	\$3.29	\$3.28	\$3.27	\$3.21	\$3.16	60,000	\$26,000	\$25,000	\$25,000	\$25,000	\$25,000

Note:

¹ Values from Tables 7,8, and 9 may not add to totals presented in Table 10 due to rounding.² Sources used to develop costs are documented in Tables 1 through 6.³ Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.⁴ Capital costs are annualized over the life cycle of the water treatment process at a discount rate of 3.5%.⁵ Costs provided include the cost of power but do not include capital costs for transmission of power to treatment facility. Costs do not include capital or operation and maintenance costs for pumping produced water to water treatment facility and pumping reclaimed water to site of end use.

Key:

bbl = barrel

ENR = Engineering News-Record

mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 15. Maximum Range of Oil and Grease and Reverse Osmosis Treatment Costs for Produced Water^{1,2,3,4}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	\$0.12	n/a	n/a	n/a	n/a	500	\$940	n/a	n/a	n/a	n/a
1,000	\$0.22	\$0.17	\$0.12	n/a	n/a	1,000	\$1,750	\$1,350	\$940	n/a	n/a
10,000	\$0.34	\$0.34	\$0.33	\$0.31	\$0.28	10,000	\$2,700	\$2,600	\$2,600	\$2,400	\$2,200
30,000	\$0.65	\$0.65	\$0.64	\$0.63	\$0.61	30,000	\$5,100	\$5,000	\$5,000	\$4,900	\$4,700
60,000	\$1.21	\$1.20	\$1.20	\$1.18	\$1.16	60,000	\$9,400	\$9,300	\$9,300	\$9,200	\$9,000

Notes:

¹ Sources used to develop costs are documented in Tables 1 through 5.

² Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.

³ Capital costs are annualized over the life cycle of the water treatment process at a discount rate of 3.5%.

⁴ Costs provided include the cost of power but do not include capital costs for transmission of power to treatment facility. Costs do not include capital or operation and maintenance costs for pumping produced water to water treatment facility and pumping reclaimed water to site of end use.

Key:

bbl = barrel

ENR = Engineering News-Record

mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 16. Maximum Brine Haul Costs^{1,2}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	n/a	n/a	n/a	n/a	n/a	500	n/a	n/a	n/a	n/a	n/a
1,000	\$0.13	\$0.06	n/a	n/a	n/a	1,000	\$980	\$490	n/a	n/a	n/a
10,000	\$0.48	\$0.47	\$0.46	\$0.41	\$0.36	10,000	\$3,800	\$3,700	\$3,600	\$3,200	\$2,800
30,000	\$0.92	\$0.92	\$0.91	\$0.88	\$0.85	30,000	\$7,200	\$7,100	\$7,100	\$6,800	\$6,600
60,000	\$2.66	\$2.65	\$2.64	\$2.59	\$2.55	60,000	\$21,000	\$21,000	\$20,000	\$20,000	\$20,000

Notes:¹ Sources used to develop costs are documented in Table 6.² Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.**Key:**

bbl = barrel

ENR = Engineering News-Record

mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 17. Maximum Brine Injection Costs^{1,2}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	n/a	n/a	n/a	n/a	n/a	500	n/a	n/a	n/a	n/a	n/a
1,000	\$0.01	\$0.006	n/a	n/a	n/a	1,000	\$86	\$43	n/a	n/a	n/a
10,000	\$0.04	\$0.04	\$0.04	\$0.04	\$0.03	10,000	\$330	\$320	\$310	\$280	\$240
30,000	\$0.08	\$0.08	\$0.08	\$0.08	\$0.07	30,000	\$630	\$620	\$620	\$600	\$580
60,000	\$0.23	\$0.23	\$0.23	\$0.23	\$0.22	60,000	\$1,800	\$1,800	\$1,800	\$1,750	\$1,750

Notes:

¹ Sources used to develop costs are documented in Table 6.

² Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.

Key:

bbl = barrel

ENR = Engineering News-Record

mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

Table 18. Sum of Maximum Oil and Grease and Reverse Osmosis Treatment, Brine Haul, and Brine Injection Costs^{1,2,3,4,5}

Reclaimed Water Unit Cost (\$US/bbl product)						Reclaimed Water Unit Cost (\$US/acre-foot product)					
Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)					Produced Water TDS (mg/L)	Reclaimed Water TDS (mg/L)				
	500	750	1000	2000	3000		500	750	1000	2000	3000
500	\$0.12	n/a	n/a	n/a	n/a	500	\$940	n/a	n/a	n/a	n/a
1,000	\$0.36	\$0.24	\$0.12	n/a	n/a	1,000	\$2,800	\$1,850	\$940	n/a	n/a
10,000	\$0.87	\$0.85	\$0.83	\$0.75	\$0.67	10,000	\$6,700	\$6,600	\$6,400	\$5,800	\$5,200
30,000	\$1.66	\$1.65	\$1.63	\$1.58	\$1.53	30,000	\$13,000	\$13,000	\$12,500	\$12,500	\$12,000
60,000	\$4.10	\$4.08	\$4.07	\$4.00	\$3.93	60,000	\$32,000	\$32,000	\$32,000	\$31,000	\$31,000

Note:

¹ Values from Tables 7, 8, and 9 may not add to totals presented in Table 10 due to rounding.² Sources used to develop costs are documented in Tables 1 through 6.³ Costs are presented in 2014 dollars and have been indexed from the source year to 2014 using ENR Construction Cost Index. These costs do not include contingencies, allowances, or unlisted items.⁴ Capital costs are annualized over the life cycle of the water treatment process at a discount rate of 3.5%.⁵ Costs provided include the cost of power but do not include capital costs for transmission of power to treatment facility. Costs do not include capital or operation and maintenance costs for pumping produced water to water treatment facility and pumping reclaimed water to site of end use.

Key:

bbl = barrel

ENR = Engineering News-Record

mg/L = milligrams per liter

n/a = not applicable

TDS = total dissolved solids

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